CHAPTER VI.

STATIONARY AGRICULTURAL IRRIGATION PUMP ENGINES

This chapter presents the project criteria under the Carl Moyer Program for stationary agricultural irrigation pump engines (stationary agricultural irrigation pump engines). It also contains a brief overview of NOx emission inventory, current emission standards, available control technology, potential incentive projects eligible for funding, and emission reduction calculation and cost-effectiveness calculation methodologies.

A. Introduction

Stationary internal combustion engines used for agricultural purposes in California are primarily utilized to power irrigation water pumps. For the purposes of the Carl Moyer Program, these engines could be considered part of the off-road equipment, because off-road engines are often utilized in stationary agricultural applications. However due to the operating characteristics specific to stationary agricultural irrigation pump engines, they are evaluated separately from the off-road equipment category, which generally covers mobile equipment such as agricultural tractors, backhoes, excavators, trenchers, and motor graders.

Off-road engines can be divided into two major categories: (1) engines less than (<) 175 brake horsepower (bhp) and (2) engines greater than or equal to (≥) 175 hp. The federal Clean Air Act Amendments (CAAA) of 1990 gave the United States Environmental Protection Agency (USEPA) exclusive authority to regulate new off-road engines. The amendments created a federal preemption that prevents states from adopting emissions standards or other requirements for off-road engines [CAA, section 209(e)]. However, Congress allowed California, upon receiving authorization from the USEPA, to adopt standards and regulations for preempted engines, with the exception of new farm and construction engines <175 hp. In other words, the ARB does not have authority to regulate off-road engines <175 hp used in farm operations. Also, the California Health and Safety Code (HSC) section 42310(e) prohibits local air districts or the State from requiring a permit for farm equipment.

According to federal definition, off-road engines do not include engines used in off-road applications which are considered stationary. Off-road engines, however, are a workable option for stationary agricultural applications. Therefore, for the purposes of the Carl Moyer Program, staff recommends that the guideline criteria for stationary agricultural irrigation pump engines be established within the framework of applying ARB/USEPA off-road engine emissions standards to stationary agricultural irrigation pump engines. Under the Carl Moyer Program, funding will be provided for voluntary reduction of NOx emissions from stationary agricultural irrigation pumps with engines 50 horsepower or greater. Section B of this chapter discusses specific criteria that must be met in order to qualify for funding from the Carl Moyer Program for this source category.

1. Emission Inventory

Agricultural irrigation pumps are powered electrically and with fuel-fired internal combustion engines. A 1995 report written by Sonoma Technology, Inc. for the SJVAPCD indicates 90 percent of irrigation pumps in the San Joaquin Valley are electrically powered. The remaining 10 percent are engine-driven pumps fueled most commonly with diesel and, to a lesser degree, with natural gas or propane. Diesel is most commonly used due to its lower cost and the limitations posed by inaccessibility to natural gas lines in certain rural areas. In general, stationary agricultural irrigation pump engines run an average of 10,000 hours before requiring an overhaul or rebuild. Depending on each engine owner's operating schedule and maintenance routine, this equates to a variety of engine lifetimes. Stationary agricultural irrigation pump engines generally have low annual operating hours, from 1,000 to 3,600 hours per year. Using this range of operating hours, an engine can run 3 to 10 years before rebuild. If an engine can be rebuilt 3 to 4 times, it is possible to get 30 to 40 years of life out of an engine. Once an engine has exhausted its useful life, the most common engine replacement practice by farmers, if they are still living or are still in the family business, is to purchase a rebuilt engine rather than a new engine.

Stationary agricultural irrigation pump engines can be considered a seasonal source of NOx emissions, although NOx emissions occur throughout the calendar year. Most NOx emissions occur throughout the spring and summer months during the primary crop growing period. In fact, seasonal NOx emissions from agricultural irrigation pump engines may be as high as 52 tons per day in the summer months throughout the San Joaquin Valley, according to a 1995 Sonoma Technology, Inc. report. According to the ARB's 1997 baseline NOx emission inventory for agricultural irrigation pumps powered by diesel engines, NOx emissions are 34 tons per day. ARB's estimated NOx emissions are based on data provided by San Joaquin Valley and Santa Barbara County Air Pollution Control Districts. Future emissions are projected to remain the same through 2010.

2. Emission Standards

Historically, the districts have not regulated emissions from stationary agricultural engines. In fact, district prohibitory rules for stationary internal combustion engines specifically exempt agricultural engines from the requirements of the district rules. Therefore, stationary agricultural engine emissions are largely uncontrolled, except in cases where engines of 1996 model year and newer are in use. These engines are subject to ARB/USEPA off-road diesel engine emission standards.

In January 1992, ARB adopted exhaust emission standards for 1996 and later model year off-road diesel cycle engines $\geq$175 hp. The USEPA has adopted virtually identical NOx emission standards for new off-road diesel cycle engines; however, the USEPA standards apply to off-road engines $\geq$50 hp. Table VI-1 lists both the ARB and USEPA standards. As shown in Table VI-1, these standards vary depending on the model year and the engine size. The combination of ARB and USEPA emission standards means that all of today's new off-road diesel cycle engines from 50 horsepower and greater have to be certified to meet a NOx emission standard of 6.9 g/bhp-hr.

ARB has also adopted optional NOx standards (emission reduction credit standards) for off-road diesel equipment. The optional NOx emission credit standards currently start at 5.0 g/bhp-hr and decrease in 0.5 g/bhp-hr increments. Beginning in 2001, the NOx emission credit standards for off-road diesel equipment will start at 4.5 g/bhp-hr and also decrease in 0.5 g/bhp-hr increments. Stationary agricultural engine projects eligible under the Carl Moyer Program must be certified to one of the emission reduction credit standards for 1996 and later model year engines. Certification must be conducted using the off-road test cycle.

Table VI-1
ARB and USEPA Exhaust Emission Standards
for New Off-Road Diesel Engines
(g/bhp-hr)

Model Year	Agency	Horsepower	NOx (g/bhp-hr)	PM (g/bhp-hr)
1996 – 2000	ARB/EPA	175-750	6.9	0.4
1997	EPA	100-<175	6.9	-
1998	EPA	50-<100	6.9	-
2000+	ARB/EPA	750+	6.9	0.4
2001+	ARB	175-750	5.8	0.16

3. Control Strategies

The purpose of this section is to discuss commercially available control technologies for stationary agricultural engine projects. The reduced-emission engines discussed are considered suitable as new engine purchases for repower opportunities. This section also provides information regarding reduced-emission engine technologies that can be purchased now, and/or have potential to become commercially available in the near term.

a. Emission-Certified Engines

New 1996 and later model year off-road diesel cycle engines from 50 horsepower and greater must comply with a NOx emission standard of 6.9 g/bhp-hr. The NOx emission standard for off-road diesel cycle engines with 175-750 hp sold in California will be reduced to 5.8 g/bhp-hr for the model year 2001 engines.

A viable and cost-effective way to reduce emissions from uncontrolled diesel engines is to substitute the engine (i.e., repower) with an emission-certified off-road compression-ignition or emission-certified off-road spark-ignition engine instead of rebuilding the existing engine to its original uncontrolled specifications. Emission-certified diesel engines are commercially available for off-road engines $\geq$50 hp that are covered under this program. The appropriate engine size for an irrigation pump will depend on a number of factors such as water demand and the size of the irrigation pump.

ARB has adopted exhaust emission standards for new large, off-road spark-ignition (LSI) engines on October 22, 1998, to be implemented beginning in 2001. The emission standards are applicable to non-preempted off-road spark-ignition engines >25 hp. The USEPA expects to propose comparable nationwide exhaust emission standards for this category of engines. The regulations require a certification process similar to that used for small off-road engines and heavy-duty off-road engines. The ARB regulations were approved recently and requirements will be phased-in over the next few years. Repowers with off-road spark-ignition engines would have to undergo applicable certification testing to verify emission levels. For purposes of the Carl Moyer Program, off-road spark-ignition engines would be required, at a minimum, to test to the off-road diesel emission standards for the applicable model year and horsepower rating.

b. Electric Motors

Another potentially cost-effective way to reduce emissions from uncontrolled engines is to replace the internal combustion engine with an electric motor instead of rebuilding the existing engine to its original uncontrolled specifications. Substituting an electric motor for an internal combustion engine on an agricultural irrigation pump significantly reduces emissions. Replacing an older electric motor for a newer electric motor on an agricultural irrigation pump does not reduce emissions. Irrigation pumps powered by electric motors are commercially available for various applications. In fact, 90 percent of current irrigation pumps are already powered by electric motors. Hence, the requirements for an electrification project to qualify for funding under the Carl Moyer Program are designed to target the replacement of the remaining 10 percent of internal combustion engines used in agricultural irrigation pumps. The viability of an electrification project will depend on a number of factors, including cost of electricity and proximity to an electric power grid.

c. Engine Retrofit Technology

Any retrofit technology must be certified by ARB before it can be sold in California, must be able to reduce NOx emissions by at least 15 percent, and must comply with established durability and warranty requirements. There are few retrofit technologies available for pre-1996 model year off-road diesel engines that would reduce NOx emissions from uncontrolled levels to the 6.9 g/bhp-hr NOx emission standard or lower. ARB recently pre-certified diesel engine retrofit kits for selected Detroit Diesel Corporation pre-1993 model year engines. The retrofit technology is certified to a NOx emission standard no greater than 5.8 g/bhp-hr. Currently, retrofit kits are available for a limited number of engine models some of which may be engines in the size range typically used for agricultural irrigation pumps. It is also possible that retrofit technologies that have been used to reduce NOx and PM emissions from on-road heavy-duty diesel engines could be used to control off-road engine emissions in some applications.

B. Project Criteria

The intent of the Carl Moyer Program is to provide early emission reductions from heavy-duty diesel engines. The approved project criteria have been designed to provide districts and equipment operators with a list of minimum qualifications that must be met in order for a project to qualify for funding. The main criteria for selecting a project are the amount of emission reductions, cost-effectiveness, and ability for the project to be completed within the timeframe of the program. The criteria also specify the method for calculating emission reductions and cost-effectiveness from reduced-NOx stationary agricultural engine projects. Reduced-NOx stationary agricultural irrigation engine projects that include engine repowers, new purchase or engine replacements with electric motors, or engine retrofits will be considered and evaluated for incentive funding.

The second through seventh project criteria listed below are new project criteria. These criteria were modified to clarify the type of repowers and retrofits allowed for agricultural irrigation pump engine projects under the Carl Moyer Program. The revised language allows for pre-1996 model year engines ($\geq$50 horsepower) to be repowered with new off-road diesel engines certified to the current standard, new off-road spark-ignited engines that test at a NOx level that meets the current standard, or new electric motors. For these years, it also allows retrofit kits that are certified to the off-road emission standard for use on off-road engines. For 1996 and later model year engines, the repowered engine would be an engine certified to the off-road credit standards (for either diesel or spark-ignited engines), or an electric motor. Retrofit kits for 1996 and later model year engines would be certified to reduce NOx emissions by at least 15 percent. The project criteria have been modified to include a requirement that all engines be tested using approved ARB test procedures.

In general, stationary agricultural engine projects qualifying for evaluation must meet, at minimum, the following criteria:

- An engine must be 50 horsepower or greater which is equivalent to an electric motor 37 kilowatts or greater;

- A new purchase of a 2000 or later model year agricultural irrigation pump engine must have an electric motor.

- A repower or retrofit of a pre-1996 model year engine 50 horsepower and greater must be with:
  1) A new off-road diesel engine certified at the 6.9 g/bhp-hr NOx emission standard for off-road engines,
  2) A new off-road spark-ignited engine that tests at a NOx level that meets the off-road diesel engine standard (i.e., 6.9 g/bhp-hr),
  3) A new electric motor, or

4) A kit that is certified to the off-road engine emission standards for use on off-road engines;

- A repower of an emission-certified off-road engine of model year~~s~~ 1996 and newer, must be with:
  1) A new off-road diesel engine certified at one of the applicable NOx emission credit standards listed in Table VI-2,
  2) A new off-road spark-ignition engine that tests at a NOx level that meets the off-road NOx emission credit standards, or
  3) A new electric motor;

- A retrofit of an emission-certified off-road engine of model year 1996 and newer, must be certified to reduce NOx emissions by at least 15% for use in off-road engines;

- Engines must be tested using ARB test procedures for off-road engines;

- The maximum project life when determining project benefits is as follows:

	Default without Documentation	Default with Documentation
New purchase/ Repower	7 years	10 years

  A different project life may be selected for approval by ARB staff. However sufficient documentation must be provided to ARB that supports the selected project life based on the actual remaining useful life.

- Emission-certified engines of the model years 1996 and later, must be certified at one of the applicable NOx emission credit standards listed in Table VI-2;

Table VI-2
Project Eligibility Criteria
1996 and Later Model Year Engines

Engine Model Year	Engine Horsepower Rating (bhp)	Qualifying NOx Level (g/bhp-hr)
1996-2000	50-750	4.5
2000+	750+	4.5
2001+	50-750	4.0

- Electric motors must only replace internal combustion engines that are fueled with diesel, and the applicant must have documentation of payment to the local utility company for power installation. This requirement of documentation also applies to new installations;

- Reduced-emission engines or retrofit kits must be certified for sale in California and must comply with durability and warranty requirements. Qualified engines could include new ARB-certified engines or ARB-certified aftermarket part engine/control devices;

- NOx reductions obtained through this program must not be required by any existing regulations or any legally binding document (i.e., MOU, MOA, etc.);

- Funded projects must operate for a minimum of five years and the agricultural stationary engine must be registered with the district throughout the specified life of the project; and

- Projects must meet a cost-effectiveness criterion of $13,000 per ton of NOx reduced.

Priority should be given to stationary agricultural irrigation engine projects which result in the greatest amount of emission reductions (e.g., engine replacements with electric motors, engine repowers with certified engines, followed by engine retrofits). This is in line with the intent of the Carl Moyer Program to provide early emission reductions, and in turn, produce the greatest air quality benefit.

C. Potential Types of Projects

The primary focus of this category of the Carl Moyer Program is to achieve emission reductions from stationary diesel agricultural irrigation engines operating in California as early and as cost-effectively as possible. The following project criteria are designed to ensure that the emission reductions expected through the deployment of electric motors, reduced-emission engines, or retrofit technologies under this program are real and quantifiable. All projects must meet a cost-effectiveness criterion of $13,000 per ton of NOx reduced. In addition, diesel repower projects are also subject to a maximum dollar amount to be granted based on the horsepower rating of the engine. The project must be operated for at least five years from the time it is first put into operation.

1. New Purchase with Electric Motors

New purchases of agricultural irrigation pump are allowed if equipped with electric motors. This new agricultural irrigation pump with an electric motor would be compared to a new pump with an off-road diesel engine certified to the current off-road NOx emission standard.

2. Repower with Emission-Certified Engines

Purchases of new emission-certified diesel off-road engines to repower uncontrolled diesel engines are expected to be the most common type of project for stationary agricultural irrigation pump engines under this program due to their wide availability. Several air districts are currently funding these projects. Purchases of new off-road spark-ignition engines to repower uncontrolled diesel engines are also an option under this program.

Under the Carl Moyer Program, a stationary agricultural irrigation pump engine repower is substituting an existing uncontrolled engine with a new off-road engine certified to a current off-road NOx emission standard, or substituting an existing certified off-road engine with a new off-road engine certified to an optional ARB NOx emission credit standard. The NOx level that would qualify a stationary agricultural irrigation pump engine repower project for funding would depend on the engine model year and the engine size, as outlined in the criteria under section B and listed in Table VI-2. For repower projects, gasoline-to-diesel repowers will not qualify for the Carl Moyer Program.

Technology for diesel to alternative fuel repowers is available; however an extensive number of spark-ignition engines have not gone through certification testing. The applicant is allowed to test large spark-ignition engines, in lieu of certification since a number of these engines have not gone through certification testing. However, testing must be conducted according to ARB test procedures for off-road engines. The new ARB LSI regulations establish a testing program, and future USEPA regulations will establish a similar testing procedure. Carl Moyer Program funds will not cover the costs of certification testing. These costs would have to be absorbed by the applicant, engine manufacturer, or another outside source.

The emission factors under section D of this chapter have been revised to account for the new OFFROAD model. The new emission factors may prevent some repower projects from qualifying for funding. Hence the emission reduction requirement for repowers and retrofits has been modified to 15 percent.

3. Replacement with Electric Motors

Replacement of uncontrolled engines with electric motors is an option under the Carl Moyer Program. During the first year of the program, applications for electric motors were scarce. This was partly due to exclusion of infrastructure costs in determining the funding amount, which resulted in higher initial out-of-pocket costs to the applicant. In an electric pumping application, peripheral equipment is needed to supply electricity to the motor. The installed cost of a new certified diesel engine is comparable to the installed cost for an electric motor plus its necessary supporting components. Districts and utility companies have indicated that many diesel pump engines are situated next to existing electric lines, so no line extension would be needed. Considering the air quality benefits of electric motors, selected infrastructure costs for necessary equipment associated with the motor (e.g., control panel, motor leads, service pole with guy wire, connecting electric line) may be included in determining the grant amount awarded.

For more remotely located irrigation pumps, some utility companies offer monetary line extension credits. Where a credit applies, the customer is responsible for the cost of the line extension (generally charged on a per foot basis) beyond what is covered by the credit. In most cases, costs associated with electric line extensions may not be covered with Moyer funds. The only instance where Moyer funds may be used toward line extensions is where the maximum amount to be funded plus funded project costs do not exceed the $13,000/ton cost-effectiveness limit. In these cases, the funds applied toward a line extension, must come from the district and would count as matching funds. This may only be applied where the applicant faces out-of-pocket expense above the line extension credit allowance (i.e., the needed line footage is outside the maximum distance provided free of charge).

Diesel-to-electric motor repowering projects are subject to the cost-effectiveness criterion of $13,000 per ton of NOx emissions reduced, as well as other criteria presented in this guideline.

4. Retrofits

Retrofit means making modifications to the engine and/or fuel system such that the retrofitted engine does not have the same specifications as the original engine. Retrofit projects may be applicable to certain off-road diesel engine families. The most straightforward retrofit projects are those that could be accomplished at the time of engine rebuild. This might entail upgrading certain engine and/or fuel system components to result in lower emission configuration. It is possible that emission control technologies that have been used to reduce NOx and PM emissions from on-road heavy-duty diesel engines could be used to control off-road engine emissions in some applications. This type of project would qualify for funding if the engine retrofit kit for uncontrolled engines is certified to 6.9 g/bhp-hr NOx emission standard or less, for use in off-road engine applications.

Staff revised emission factors under section D of this chapter to account for the new OFFROAD model. The new emission factors may prevent some retrofit projects from qualifying for funding. Hence, emission reduction requirement for repowers and retrofits has been modified to 15 percent.

5. Sample Application

In order to qualify for incentive funds, districts will make applications available and solicit bids for reduced-emission projects from stationary agricultural engine operators. A sample application form is included in Appendix G. The applicant must provide at least the following information, as listed in Table VI-3 below:

Table VI-3 Minimum Application Information Stationary Agricultural irrigation pump Projects	
1. Air District: 2. Applicant Demographics Company Name: Business Type: Mailing Address: Location Address: Contact Number: 3. Project Description Project Name: Project Type: Equipment Function: 4. NOx Reduction Incremental Cost Effectiveness Analysis Basis: (Mileage/Fuel/Hours of Operation) 5. VIN or Serial Number: 6. Application: (Repower, Retrofit or New) 7. Annual Diesel Gallons Used: 8. Hours of Operation: 9. Old Engine Information Horsepower Rating: Engine Make: Engine Model: Engine Year:	10. New Engine Information Horsepower Rating: Engine Make: Engine Model: Engine Year: Fuel Type: 11. NOX Emissions Reductions Baseline NOx Emissions Factor (g/bhp-hr): NOx Conversion Factors Used: Reduced NOx Emissions Factor (g/bhp-hr): Estimated Annual NOx Emissions Reductions: Estimated Lifetime NOx Emissions Reductions: 12. Percent Operated in California: 13. Project Life (years): 14. Cost ($) of the Base Engine: 15. Cost ($) of Certified LEV Engine: 16. PM Emissions Reductions Baseline PM Emissions Factor (g/bhp-hr): PM Conversion Factors Used: Reduced PM Emissions Factor (g/bhp-hr): Estimated Annual PM Emissions Reductions: Estimated Lifetime PM Emissions Reductions: 17. District Incentive Grant Requested:

D. Emission Reduction and Cost-Effectiveness

1. Emission Reduction Calculation

In general, the emission reduction benefit represents the difference in the emission level of a baseline and reduced-emission engine. In situations where the model year of the equipment and the model year of the existing engine are different, the model year of the engine will be used to determine the baseline emission factor for emission reduction calculations. The emission level is calculated by multiplying an emission factor, a conversion factor and an activity level. Because the conversion factor and the activity level could be different for the baseline and reduced emission engine, the emission level should be calculated first and then the difference taken to determine the emission reduction. The examples in the previous version, where the emission reductions were simply based on the difference in emission factors, assumed that there was no change in the conversion factor or activity level. For a stationary agricultural irrigation pump, the activity level is either the annual hours of operation or fuel consumed. Qualification with the cost-effectiveness criteria will be based upon NOx emissions only. Calculations shall be done using either the fuel consumption method or hours of operation method described below consistent with the type of records that will be maintained over the life of the project.

In absence of manufacturer "guaranteed" emission factors, Table VI-4 lists the default baseline NOx emission levels for pre-1996 model year diesel engine repower and retrofit projects to be used when determining the NOx emission difference between the existing engine and the replacement engine. The new baseline NOx emission factors reflect the recently adopted emissions inventory for off-road large compression-ignited engines, greater than or equal to 25 horsepower. The OFFROAD model incorporated recent data and reflects currently adopted regulations. Manufacturers applied some of the technology advancements in the fuel management systems used in 1988 and newer on-road diesel-powered engine to similar off-road engines. Emission reductions from this technology are also reflected in the new emission factors. Also, the engine default load factor has changed from 0.75 to 0.65.

Table VI-4
Baseline NOx Emission factors for
Uncontrolled Off-Road Heavy-Duty Diesel Engines
(g/bhp-hr)

Model Year	50 –120 hp	120 + hp
Pre - 1988	13	11
1988 – 1996	8.75	8.17

The applicant would have the option of testing the baseline (uncontrolled) engine using an ARB approved test procedure to determine actual emissions. The maximum allowable baseline emissions for pre-1996 engines as determined through in-use testing is 13 g/bhp-hr ($\leq$120 hp) and 11 g/bhp-hr (>120 hp).

If the annual hours of operation are the basis for determining the emission reductions, the conversion factor is the horsepower of the engine multiplied by the load factor of the application and the activity level should be based on the actual hours of the equipment. The load factor is an indication of the amount of work done, on average, by an engine for a particular application, given as a fraction of the rated horsepower of the engine. The load factor is different for each application. If the actual load factor is known for an engine application, it should be used in calculating the emission reductions. Another variable in determining the emission reductions is the number of hours that the equipment operates a year as counted by an hour meter. If the load factor is not known, the default load factor listed in Table VI-5 should be used in the emission reduction calculation.

If the annual fuel consumption is used, an energy consumption factor should be calculated and the activity level should be based on actual annual fuel receipts or other documentation. The energy consumption factor converts the emission factor in terms of g/bhp-hr to g/gallon of fuel used. There are two ways of calculating the energy consumption factor: 1) by dividing the horsepower of the engine by the fuel economy in units of gallons/hour or 2) by dividing the density of the fuel by the brake-specific fuel consumption of the engine. A default energy consumption factor is listed in Table VI-6. While actual fuel receipts support the annual fuel consumption of the baseline engine, the annual fuel consumption of the reduced-emission engine is an estimate proportionate to the change in the energy fuel consumption factor. For example, a reduced-emission engine having an energy consumption factor of 20, replacing a baseline engine which uses 3,696 gallons/year and has an energy consumption factor of 17.56, would have an estimated annual fuel consumption of 3,234 gallons/year. Future fuel receipts or equivalent documentation should be submitted, throughout the project life, as verification of this estimate.

Table VI-5
Default Factors for Stationary Agricultural Irrigation Pumps
50+ Horsepower

Energy Consumption Factor (bhp-hr/gal)	17.56
Load Factor	0.65

2. Cost-Effectiveness Calculation

The portion of the cost for a repower project to be funded through the Carl Moyer Program is the difference between the total cost of purchasing and installing the new emission-certified engine or electric motor and the total cost of rebuilding the existing engine.

Only the amount of money provided by the program and any local district match funding is to be used in the cost-effectiveness calculations. The one-time incentive grant amount is to be amortized over the expected project life (at least five years) and with a discount rate of five percent. The amortization formula (given below) yields a capital recovery factor, which, when multiplied with the initial cost, gives the annual cost of a project over its expected lifetime.

Capital Recovery = $[(1 + i)^n (i)]/[(1 + i)^n - 1]$

Where, i = discount rate (5 percent)
n = project life (at least five years)

The discount rate of five percent reflects the opportunity cost of public funds for the Carl Moyer Program. This is the level of earning that could be reasonably expected by investing state funds in various financial instruments, such as U.S. Treasury securities. Cost-effectiveness is determined by dividing the annualized cost by the annual NOx emission reductions. These calculations are explained in detail in the next section of this chapter.

3. Examples

Example 1 – Agricultural Irrigation Pump Repower: Consider a farmer faced with the opportunity to replace a 1980 model year diesel engine rated at 120 horsepower used to power an irrigation water pump with a new, certified off-road diesel engine rated at 150 horsepower during the normal rebuild period. In this case, the cost of the new, emission-certified diesel engine is $7,900 whereas the cost to purchase a rebuilt engine would be $5,500. The cost of a non-resettable hour meter is $300. The old engine operated 2,000 hours annually. The project life is 7 years.

<u>Emission Reduction Calculation</u>

Baseline NOx Emissions:	13.0 g/bhp-hr
Baseline Horsepower:	120 hp
Baseline Load Factor:	65%
Reduced NOx Emissions:	6.9 g/bhp-hr
Reduced Horsepower:	150 hp
Reduced Load Factor:	120 hp / 150 hp * 65% = 52%
Annual Operating Hours:	2,000 hours/year
ton/907,200 grams:	Converts grams to tons

(13.0 g/bhp-hr * 120 hp * 0.65) – (6.9 g/bhp-hr * 150 hp * 0.52) * 2,000 hrs/yr * ton/907,200 g =
1.0 ton/year NOx emissions reduced

<u>Cost-Effectiveness Calculations</u>

The annualized cost is based on the portion of incremental project costs funded by the Carl Moyer Program, the expected life of the project (5 years at a minimum), and the interest rate (5 percent) used to amortize the project cost over the project life. The incremental capital cost to the operator for this purchase and the maximum amount that could be funded through the Carl Moyer Program fund are determined as follows:

Incremental Capital Cost = $ 8,200 - $ 5,500 = $ 2,700
Max. Amount Funded = $ 2,700
Capital Recovery = $[(1 + 0.05)^7 (0.05)]/[(1 + 0.05)^7 – 1] = 0.17$
Annualized cost = $ 2,700 * 0.17 = $ 459/year
Cost-Effectiveness = ($ 459/year)/(1.0 tons/year) = **$ 459/ton NOx reduced**

The project meets the cost-effectiveness limit of $13,000 per ton NOx reduced. This project would qualify for the maximum amount of grant funds ($2,700).

Example 2 - Agricultural Irrigation Pump Repower: Consider a similar example, where an uncontrolled diesel engine (1980, 13 g/bhp-hr NOx) used to power an irrigation water pump is replaced with a new, certified off-road diesel engine (150 hp, 6.9 g/bhp-hr NOx). However, in this example the annual fuel consumption is provided. The energy consumption factor for the uncontrolled engine is unknown while the energy consumption factor for the new engine calculates to about 19 hp-hr/gal. The cost of the new, emission-certified diesel engine is $7,900 whereas the cost to purchase a rebuilt engine would be $5,500. The farmer lists in the application that the new engine will use 4,600 gallons of fuel annually for a project life of 7 years. Since this farmer lists fuel consumption, a non-resettable hour meter is not needed. The emission reduction and cost effectiveness for this project are calculated as follows:

<u>Emission Reduction Calculation</u>

Baseline NOx Emissions:	13.0 g/bhp-hr
Baseline Energy Consumption Factor:	17.56 hp-hr/gal
Baseline Annual Fuel Consumption:	4,600 gallons/year
Reduced NOx Emissions:	6.9 g/hp-hr
Reduced Energy Consumption Factor:	19 hp-hr/gal
Reduced Annual Fuel Consumption:	(17.56 / 19)hp-hr/gal * 4,600 gal/yr = 4,251 gal/yr
ton/907,200 grams	Converts grams to tons

[(13.0 g/bhp-hr * 17.56 hp-hr/gal * 4,600 gal/yr) – (6.9 g/bhp-hr * 19 hp-hr/gal * 4,251 gal/yr)] * ton/907,200 g = **0.54 tons/yr NOx emissions reduced**

<u>Cost-Effectiveness Calculations</u>

The annualized cost is based on the portion of incremental project costs funded by the Carl Moyer Program, the expected life of the project (7 years in this example), and the interest rate (5 percent) used to amortize the project cost over the project life. The incremental capital cost to the fleet operator for this purchase and the maximum amount that could be funded through the Carl Moyer Program fund are determined as follows:

Incremental Capital Cost	= $ 7,900 - $ 5,500 = $ 2,400
Max. Amount Funded	= $ 2,400
Capital Recovery	= $[(1 + 0.05)^7 (0.05)]/[(1 + 0.05)^7 – 1] = 0.17$
Annualized cost	= $ 2,400 * 0.17 = $ 408/year
Cost-Effectiveness	= ($ 408/year)/(0.54 tons/year) = **$ 755/ton NOx reduced**

The project meets the cost-effectiveness limit of $13,000 per ton NOx reduced. This project would also qualify for the maximum amount of grant funds ($2,400).

Example 3 - Agricultural Irrigation Pump Electrification: Consider a farmer who applies for a Carl Moyer program grant for the purchase of an electric motor (150 hp, 0 g/bhp-hr NOx) to replace an uncontrolled diesel engine (208 bhp, 1980, 11 g/bhp-hr NOx) used to power an irrigation water pump. There is currently an electric power grid in the immediate vicinity of the pump and no electric line extension is needed. The installed cost of the new electric motor, control panel, motor leads, dropping a power line, and setting up a circuit breaker is $14,602 whereas the cost to rebuild the old engine would be $5,500. The cost of a non-resettable hour meter is $300. The new engine will operate 2,000 hours annually, for a project life of 7 years. The emission reduction and cost effectiveness for this project are calculated as follows:

Emission Reduction Calculation

Annual NOx Reductions (tons/year) =

> **[(NOx Emission Factor * Load Factor * Horsepower)$_{baseline}$ – (NOx Emission Factor * Load Factor * Horsepower)$_{reduced}$] * Annual Hours of Operation * (ton/907,200 grams)**

Where,

Baseline NOx Emission Factor:	11.0 g/bhp-hr
Reduced NOx Emission Factor:	0 g/bhp-hr
Load Factor:	65%
Baseline Horsepower:	208 hp
Reduced Horsepower:	150 hp
Annual Hours of Operation:	2,000 hours

Hence, estimated reductions are:

[(11.0 g/bhp-hr * 0.65 * 208 hp) – (0 g/bhp-hr * 0.65 * 150 hp)] * 2,000 hrs/yr * ton/907,200 g = **3.28 tons/year NOx emissions reduced**

Cost and Cost-Effectiveness Calculations

The annualized cost is based on the portion of incremental project costs funded by the Carl Moyer Program, the expected life of the project (7 years in this example), and the interest rate (5 percent) used to amortize the project cost over the project life. The incremental capital cost to the fleet operator for this purchase, with Carl Moyer Program funds, is determined as follows:

Incremental Capital Cost	= $14,602 - $5,500 = $9,102
Capital Recovery	= $[(1 + 0.05)^7 (0.05)]/[(1 + 0.05)^7 – 1] = 0.17$
Annualized Cost	= (0.17)($9,102) = $1,547/yr
Cost-Effectiveness	= ($1,547/yr)/(3.28 tons/yr) = **$472/ton**

The project meets the cost-effectiveness limit of $13,000/ton NOx reduced. This project would qualify for the maximum amount of grant funds ($9,102).

Example 4 – Agricultural Irrigation Pump "Diesel-to-Natural Gas" Repower: The following example was added to illustrate the cost effectiveness calculations for a diesel-to-natural gas engine repower project.

Consider a farmer faced with the opportunity to replace a model year 1980 diesel engine rated at 165 hp used to power an irrigation water pump. The farmer is replacing the old uncontrolled engine (11 g/bhp-hr NOx) with a new, optionally certified off-road natural gas engine rated at 150 hp (4.5 g/bhp-hr NOx) during the normal rebuild period. In this case, the cost of the new, emission-certified off-road natural gas engine is $23,500 whereas the cost to purchase a rebuilt diesel engine would be $5,500. The cost of a non-resettable hour meter is $300. The new engine will operate 2,000 hours annually, for a project life of seven years. The emission reduction and cost effectiveness for this project are calculated as follows:

Emission Reduction Calculation

Baseline NOx Emissions	=	11.0 g/bhp-hr
Baseline Horsepower	=	165 horsepower
Baseline Load Factor	=	65%
Reduced NOx Emissions	=	4.5 g/bhp-hr
Reduced Horsepower	=	150 horsepower
Reduced Load Factor	=	71%
Annual Operating Hours	=	2,000 hours/year
Convert grams to tons	=	ton/907,200 grams

[(11.0 g/bhp-hr * 165 hp * 0.65) – (4.5 g/bhp-hr * 150 hp * 0.71)] * 2,000 hours/year * ton/907,200 g = **1.5 ton/year NOx emissions reduced**

Cost-Effectiveness Calculations

The annualized cost is based on the portion of incremental project costs funded by the Carl Moyer Program, the expected life of the project (seven years in this example), and the interest rate (5 percent) used to amortize the project cost over the project life. The incremental capital cost to the operator for this purchase and the maximum amount that could be funded through the Carl Moyer Program fund are determined as follows:

Incremental Capital Cost	= $ 23,800 - $ 5,500 = $ 18,300
Max. Amount Funded	= $ 18,300
Capital Recovery	= $[(1 + 0.05)^7\ (0.05)]/[(1 + 0.05)^7 – 1] = 0.17$
Annualized cost	= $18,300 * 0.17 = $ 3,111/year
Cost-Effectiveness	= ($ 3,111/year)/(1.5 tons/year) = **$ 2,074/ton**

The project meets the cost-effectiveness limit of $13,000 per ton NOx reduced. This project would qualify for the maximum amount of grant funds ($18,300).

E. Reporting and Monitoring

Stationary agricultural engine operators participating in the Carl Moyer Program must keep appropriate records during the life of the project. During the project life, the district has the authority to conduct periodic checks or solicit operating records from the applicant that has received Moyer funds. This is to ensure that the engine is being operated as stated in the project application.

1. Reporting

The district has the authority to conduct periodic checks or solicit operating records from the applicant that has received Carl Moyer Program funds. This is to ensure that the engine is operated as stated in the program application. Hence, the applicant must maintain operating records and have them available to the district upon request. Records must be retained and updated throughout the project life and be made available to the district upon request. Annual records must contain, at a minimum, total actual hours operated, or estimated amount of fuel used. Where records of actual hours of operation are chosen, the engine must be equipped with a non-resettable hour meter. The cost of the hour meter shall be included in the capital cost of the engine for determining grant monies awarded. For electrification projects, the applicant must have documentation of payment to the local utility company for power installation.

2. Monitoring

Minimal monitoring may be necessary to ensure the program incentive monies are being applied toward the project as specified in the application. It is recommended that the districts conduct initial and/or periodic inspection of the equipment, especially when an electric motor is replaced for an internal combustion engine. To ease the tracking of the equipment over the life of the project, a district registration certificate could be issued to the equipment owner, consisting of minimal descriptive information.

F. References

1. California Air Pollution Control Officer's Association (CAPCOA) Portable Equipment
   Rule Piston IC Engine Technical Reference Document, May 19, 1995.

2. California Air Resources Board, Stationary Source Division, Emissions Assessment Branch, Process Evaluation Section, *CAPCOA/ARB Proposed Determination of Reasonably Available Control Technology and Best Available Retrofit Control Technology for Stationary Internal Combustion Engines*, draft report, December 3, 1997.

3. Sierra Research, Inc., *Evaluation of VOC and NOx Control Measures*, Report No. SR98-04-01, April 2, 1998.

4. Sonoma Technology, Inc., *Emission Inventory of Agricultural Internal Combustion Engines Used for Irrigation in the SJVUAPCD*, Final Report STI-95240-1569-FR, August 1996.

5. United States Environmental Protection Agency, *AP-42, Compilation of Air Pollutant Emission Factors*, Fifth Edition, Volume I, Appendix A, January 1995.